SCOPE OF BLOCKCHAIN TECHNOLOGY AND ITS IMPLEMENTATION CHALLENGES FOR SOCIAL, ECONOMIC, AND ENVIRONMENTAL SUSTAINABILITY IN HEALTHCARE SECTOR (KARNATAKA AND UTTAR PRADESH)

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ABSTRACT

Keywords: Blockchain Technology, Blockchain in Healthcare, Indian Healthcare Sector, Sustainable Healthcare, Modified Generalized Fuzzy Evaluation Method (MGFEM), Latent Dirichlet Allocation (LDA), Value-Focused Thinking (VFT), Analysis of Variance (ANOVA)

Healthcare is essential for the overall development and well-being of any nation, covering prevention, diagnosis, treatment, and management of illnesses. The Indian healthcare sector is complex and unique, shaped by a consultancy-driven approach that integrates organized and unorganized services, large and diverse population along with variety of treatment modalities such as Ayurveda, Allopathy, Homeopathy, and Unani. Therefore, the medical system is under stress and faces challenges like loss of medical history, inefficient and poor resource management, fluctuating treatment costs, an uneven distribution of medical facilities and difficulty in accessibility among others. The intervention of appropriate technology is essential to address these challenges. This research work explores the potential of Blockchain technology to resolve these challenges and ensure social, economic, and environmental sustainability while determining the issues to its implementation.

This research provides significant analysis of the challenges faced by Indian healthcare from stakeholders' perspective primarily focusing on two states, Karnataka, and Uttar Pradesh, reflecting country's diversity. Based on stakeholder discussions, the study employs Value-Focused Thinking (VFT) to outline key objectives of healthcare, align them with three dimensions of sustainability and identify appropriate blockchain attributes that can address the challenges. Further, the research employs ANOVA to examine differences in challenges faced by stakeholders based on demographic factors such as location, gender, income, and education. The next phase prioritizes identified blockchain attributes based on expert's preferences for a sustainable healthcare system using Modified Generalized Fuzzy Evaluation Method (MGFEM). Finally, the Latent Dirichlet Allocation (LDA) method is utilized to identify and categorize key issues from development and end user perspective, resulting in an implementation issues matrix designed to facilitate the adoption journey of Blockchain in the Indian healthcare. Further, sentiment Analysis is used for expert opinions to gauge their views about feasibility of implementing Blockchain for Indian healthcare Sector.

INTRODUCTION

Healthcare industry is the lifeline of any economy. Healthcare is improving or maintaining the health by diagnosing, treating, and preventing the injury, illness either physical or mental which is delivered by health service providers viz. physicians, support staff, hospital systems etc [1]. Healthcare caters to multitude of facets viz. medical emergencies, diseases, accidents, and these cases need to be attended, diagnosed, and treated in a trusted, effective and transparent manner. Healthcare is of high importance for any country for its overall development and growth [2].

According to a report by Constitution of WHO [3], Access to a standard healthcare is the basic right of every human being without any discrimination based on caste, creed or gender. However, research shows that access to standard healthcare service is inadequate and poor in developing countries compared to developed nations. In particular, the people who suffer from lack of healthcare facilities are poor and mainly from unprivileged background. Furthermore, scarce access to healthcare deteriorates public health and increases poverty [4], [5].

While India has shown significant growth with respect to GDP, the country needs an improvement with respect to healthcare ecosystem. According to a report by World Health Organization(WHO) 2023, India falls at a 112^{th} position of the list among 167 countries reflecting sluggish growth in healthcare. India's total healthcare spending (out-of-pocket and public), at 3.2% of GDP, as per World Bank reports, is way lower than that of other countries. According to WHO health Statistics 2022, the physician to patient ratio in India is lower than Russia, UK, USA, Brazil and China. However, there are optimistic plans to take this health expenditure to ~5% by 2025. Despite these efforts, India finds it difficult to establish an accessible and trusted healthcare ecosystem for its stakeholder viz. health service providers, governance, and citizens among others. The healthcare in India is still in volatile state due to limited and mismanaged resources, opaque service compliance and random expense pattern for treatment. Further, the skewed medical facilities distribution in the rural and urban areas has resulted in differences of healthcare delivery to people staying in those locations.

The challenges faced in Indian Healthcare ecosystem requires mitigation through technological innovations and capabilities. Extant research emphasizes on the aspects like transparency, trust, disintermediation, non-repudiation, benchmarking of processes and practices, traceability, and data integrity along with a sustainable transformation catering to social, economic, and environmental factors for its holistic success to stimulate the Indian Healthcare system for an improvised and more effective format. A recent advancement in Technological landscape viz.

Blockchain Technology promises to offer aspects like trust, transparency, traceability, data integrity, disintermediation, and nonrepudiation among others in the host systems [8], [9], [10], [11]. There have been multitude of research around Blockchain technology deployment in Healthcare due to its ability to handle the issues in Healthcare ecosystem [2], [12], [13]. Blockchain Technology offers many of the aspects as a feature to the host systems. However, it is critical to understand and articulate the utility of Blockchain Technology specific to the Indian Healthcare System.

Our first part of the research is a significant contribution for Blockchain Technology adoption in the Indian Healthcare ecosystem from a stakeholder viewpoint. We perform Value-Focused Thinking (VFT) based discussions with the different stakeholders and articulate the key challenges of Indian Healthcare System which can be addressed by adoption of Blockchain Technology by identifying Blockchain technology attributes that are crucial for Indian Healthcare System. The research also illustrates how the adoption of blockchain technology in the Indian healthcare system can support social, economic, and environmental sustainability of the system by mapping three pillars of sustainability to blockchain technology attributes. Further, the research employs ANOVA to examine differences in challenges faced by stakeholders based on demographic factors such as location, gender, income, and education. It is important to know the difference in the challenges across different demographic parameters due to country's diverse nature.

The second part of research employs the Modified Generalized Fuzzy Evaluation Method (MGFEM) to prioritize Blockchain attributes and do structural adjustments that are best fit for Indian Healthcare sector. This methodology facilitates the identification of crucial blockchain attributes, as per the prioritization determined by experts who are actively involved in the implementation process of blockchain technology. Finally, the Latent Dirichlet Allocation (LDA) method is utilized to identify and categorize key issues from development and end user perspective, resulting in an implementation issues matrix designed to facilitate the adoption journey of Blockchain in the Indian healthcare. Further, sentiment Analysis is used for expert opinions to gauge their views about feasibility of implementing Blockchain for Indian healthcare Sector.

OBJECTIVES

The Indian healthcare system is far more complex than the ones in other countries with many organized and unorganized players. The use cases developed erstwhile cannot be replicated in the Indian context due to availability of different line of treatments, lack of proper maintenance of data, standardized insurance coverages, high variability in healthcare systems[14], [15], [16], [17], [18]. Thus, it is important to assess and understand the systemic changes that need to be deployed for Blockchain Technology for its suitability to the Indian Healthcare System.

Discussions are being held with various stakeholders in the Indian healthcare system to understand the challenges faced by them and their requirements for implementing Blockchain Technology. The research objectives aim to achieve the following outcomes.

1. To Analyse the Current State of Healthcare Sector in Karnataka and Uttar Pradesh:
    - Assess the existing challenges and inefficiencies within the Indian healthcare system from a stakeholder perspective.
2. To Explore the Potential of Blockchain Technology in Healthcare ensuring social, economic, and environmental sustainability:
    - Identify the key attributes of blockchain relevant to healthcare in India to address the challenges identified from previous objective.
    - Map the attributes of Blockchain technology to social, economic, and environmental sustainability. The attributes can map to one or more dimensions of sustainability.
    - Prioritize the Blockchain Technology attributes based on their importance with respect to Indian Healthcare sector.
3. To Assess the Feasibility and Challenges of Implementing Blockchain in Indian Healthcare Sector:
    - Identify and categorise the issues in implementation of blockchain for Indian healthcare sector.
4. To Develop Recommendations for Policymakers and Practitioners:
    - Provide actionable insights and strategies for policymakers to support blockchain adoption in Indian healthcare.

LITERATURE REVIEW

Role of Sustainability in Indian Healthcare Sector

Technological advancements stand as a significant achievement for the Indian economy, showcasing success across various sectors. The healthcare landscape has improved due to liberalization and the engagement of private players [19]. Post-1947 independence until 1978, healthcare was under public sector. The Alma Ata Primary Healthcare Act marked a turning point, catalysing healthcare delivery enhancement. The 1983 introduction of the National Health Policy aimed to ensure universal primary healthcare access but faced implementation challenges. The 2005 National Rural Health Mission (NHRM) aimed to address gaps but faced hurdles such as transparency and intermediary roles [11], [20]. Recent decades have seen considerable changes in healthcare delivery due to increased private sector involvement. However, service consistency remains a challenge, varying based on urban/rural disparities and economic accessibility. Hence, India needs a more robust healthcare delivery mechanism.

The landscape of Indian healthcare is intricate and challenging, characterized by mix of organized and unorganized health services, issues in personnel management, and service disparities. Challenges such as a shortage of skilled workforce, inflation, financial constraints, resource allocation, and quality concerns hinder efficient healthcare in India [15]. Information asymmetry among stakeholders exacerbates the situation [9]. Additional hurdles include fortified drugs in supply chains, transparent diagnostics, and healthcare infrastructure issues [19], [20]. Government initiatives like the National Health Insurance Scheme (NHIS) aim to address these issues but face obstacles such as lack of awareness and accessibility [21], [22]. Private insurers primarily target urban and affluent segments, leaving gaps in coverage for others [16], [23]. Lack of awareness, settlement obligations, and legal complexities deter beneficiaries from utilizing insurance schemes [24], [25].

Lack of transparency and trust in fund management poses significant hurdles in healthcare, leading to emotional, social, and financial implications [13], [26]. Data issues expose crucial patient information [27]. Integration of healthcare information in India faces challenges due to stakeholders operating in silos, resulting in redundant diagnostics, monetary and non-monetary challenges and inefficiencies [28]. Interoperability issues lead to opaque healthcare services and hinder digital record availability, affecting diagnostic accuracy and treatment precision [29]. Drug pricing and counterfeit drugs are major concerns in Indian healthcare's drug supply

chains [30], [31], [32], [33]. Compliance with clinical trials and drug awareness are additional challenges [34], [35].

Drawing from the points, the essential goal for Indian healthcare lies in achieving sustainable transformation, aligning social, environmental, and economic aspects with stakeholder needs. Eliminating disparities in cost, location, identity, and quality of healthcare offerings is imperative. Government initiatives such as the National Population Policy (NPP) 2000 and National Health Policy 2002, National Aids Prevention and Control Policy 2004 and 10th five-year plan, aim to elevate healthcare services. Providing a 5-year tax holiday for private healthcare providers outside major cities is a step toward reducing ecosystem disparities. Despite these efforts, Indian healthcare must address various parameters, as depicted in Table 1 comparing health indicators with other BRICS nations.:

Table 1: Comparative aspects of BRICS Nations

Health Indicators	Brazil	Russia	India	China	South Africa
Current health Expenses, 2017(% of GDP)	9.5%	5.3%	**3.5%**	5.2%	8.1%
Birth rate, (Per 1000 people) 2018	13.9	11.5	**17.9**	10.9	20.5
Physicians (Per 1000 people) 2018	2.2	4	**0.9**	2	0.9
Life Expectancy at Birth (2018)	75.7	72.7	**69.4**	76.7	63.9

The data from the table indicates India's concerning position compared to other BRICS nations [36]. World Bank analysis reveals that only 33% of healthcare expenditure is allocated to public healthcare, one of the lowest globally [37]. In 2023, India ranked 112th out of 167 countries in global health and health system rankings (WHO Report), as measured by the Health Index Score. According to WHO Health Statistics (2022), India also exhibits a notably poor Physician to Patient ratio compared to other countries. Figure 1 below illustrates the Physician to Patient ratio across different nations.

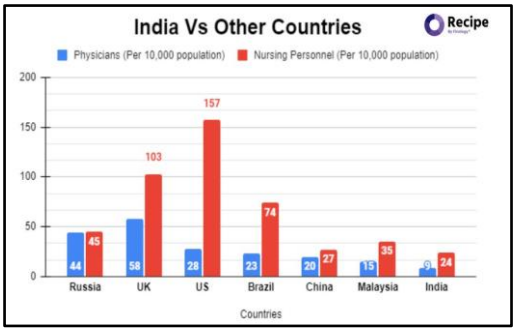


Figure 1: Physician to patient Ratio

Figure 2 summarizes the key challenges confronting Indian Healthcare, derived from existing research. These challenges underscore the urgent need for sustainable transformation in Indian Healthcare, ensuring balanced development across social, environmental, and economic dimensions.

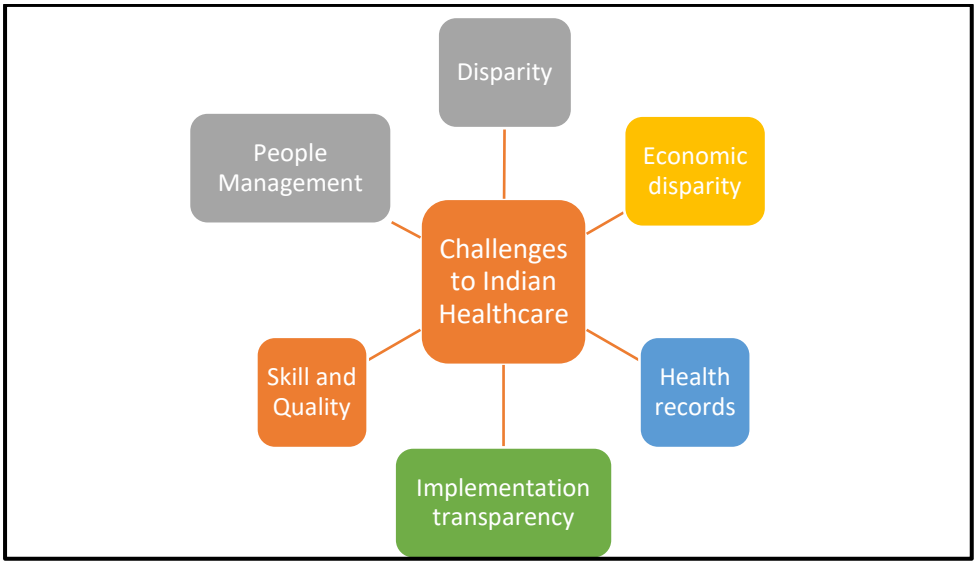


Figure 2: Challenges to Healthcare

Sustainable enhancement of Indian Healthcare hinges on the Triple Bottom Line (TBL) approach [38] as summarised in Figure. 3. This framework integrates social, economic, and environmental dimensions to meet present needs without compromising future generations' requirements [39]. The need of sustainability reverberates across dimensions of research and practice [40], [41], [42]. Healthcare's sustainable evolution prioritizes optimal profits while ensuring stakeholder benefits across social and environmental realms [43], [44], [45].

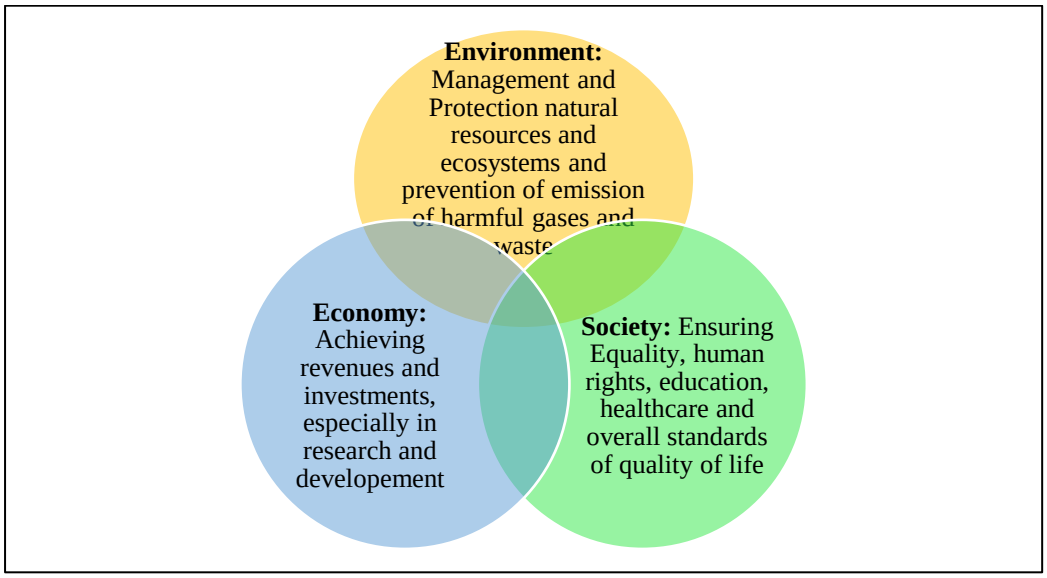

Environment: Management and Protection natural resources and ecosystems and prevention of emission of harmful gases and waste
Economy: Achieving revenues and investments, especially in research and developement
Society: Ensuring Equality, human rights, education, healthcare and overall standards of quality of life

Figure 3: Triple Bottom Line Approach of Sustainable Development

The key challenge lies in integrating and balancing three sustainability aspects—financial stability, competitiveness, and ecological and social demands [46]. Economic improvement aims to enhance living standards [47]. In India's healthcare sector, rural populations lack access to top-notch medical facilities due to location and affordability issues, highlighting economic challenges. The lack of communication between different stakeholders has costed lives of patients apart from money [48]. Environmental sustainability involves practices that preserve resources for future generations [49], achievable through stakeholder communication for resource planning and policy making [50]. Optimizing resource usage and energy consumption fosters environmental sustainability. Social sustainability focuses on empowering groups previously considered minorities, diversity and non-inclusion [51], can be achieved through transparent, trusted, and interoperable solutions [52] to promote inclusivity and reliability in healthcare [53].

Blockchain Technology and applications in healthcare

Blockchain technology has garnered significant public interest recently, with potential for revolutionizing various sectors. Researchers and experts continually explore new applications for the technology. The concept originated in the research of Haber and Stornetta in 1991 [54]. This ideation was later developed with introduction of Merkel Tree [55]. However, it gained momentum in 2008 with the implementation of the bitcoin blockchain by Satoshi Nakamoto [56]. aiming to establish trust, transparency, and decentralization thus mitigating the control of entire data by one person. Blockchain offers cryptographic capabilities ensuring transaction immutability, order, and integrity [4], [9], [10].

The initial practical use of Blockchain Technology, namely the cryptocurrency Bitcoin [56], is resistant to data alterations due to its system design[56], [57]. The "Block" concept stores data, while the "Chain" connects blocks cryptographically, preventing data alterations and enabling traceability. Blockchain technology finds applications across various sectors, including business, society, and governance [12]. Adoption is notable in industries such as Industrial Products and Manufacturing (12%), Energy and Utilities (12%), Healthcare (11%), Government (8%), Retail and Consumer Goods (4%), and Media (1%).

Blockchain technology has significant potential to positively disrupt healthcare, particularly in ensuring trusted and tamper-proof electronic health record (EHR) maintenance. Patient medical records require confidentiality and accuracy for proper diagnosis and treatment [58]. Patient medical records require confidentiality and accuracy for proper diagnosis and

treatment. Azaria et al. proposed a Blockchain-based solution for maintaining medical records. [59], addressing the diverse formats and sizes of medical data, akin to typical big data setups [60]. Peterson et al. further contributed by ensuring data security and integrity in EHRs using Blockchain [61].

Blockchain plays a crucial role in the Drug Supply Chain by enabling traceability, preventing counterfeit drugs [62], [63], [64]. Prototypes, including IBM Hyperledger, ensure quality control [65]. In biomedical research, Blockchain safeguards data integrity and anonymity, especially in clinical trials [66], [67]. Ethereum-based prototypes demonstrate maintaining data integrity in clinical trials [68]. Blockchain, in tandem with Internet of Things (IoT), enables Remote Patient Data Monitoring. IoT devices gather biomedical data, stored and analysed on the Blockchain Network [2], [62]. This allows continuous monitoring of high-risk patients and alerts in emergencies. Additionally, it extends high-quality medical facilities to remote areas. [2], [69].

Blockchain's auditability, traceability, and transparency benefit trusted health insurance [70], [71], [72], ensuring accountability and data privacy [73]. Integration if Blockchain Technology with data intelligence enables Health data analytics, enhancing processing capabilities [74], [75], [76], [77]. Understanding various applications of Blockchain in healthcare is crucial for assimilating current adoption trends. Below are the applications across healthcare dimensions, outlined in Table 2.

Table 2: Applications of Blockchain technology in different dimensions of healthcare

References	Use Case in Healthcare
[78],[79],[80],[81],[82],[83],[84],[85],[86] [87],[88],[89],[28],[90]	Electronic Health Record
[65],[91],[92],[79],[64]	Drug Supply Chain
[66],[93],[94],[95],[96],[97]	Biomedical Research
[98],[99],[100],[101]	Remote Patient Monitoring
[25],[78],[79],[82]	Health Insurance
[102],[103],[104]	Health Data Analytics

After examining extant research, below technological attributes of Blockchain are identified in Table 3. This is utilized for mapping in VFT advancement.:

Table 3: Blockchain Attributes

S. No.	Blockchain Attributes	References
B01	Decentralized	[105], [106], [107]
B02	Disintermediation	[11], [108], [109]
B03	Non-Repudiation	[110], [111], [112]
B04	Distributed	[113], [114], [115]
B05	Immutability	[56], [116]
B06	Token Mechanism	[117], [118]
B07	Simplified Auditing	[8], [119], [120]
B08	Trust	[121]
B09	Consensus Mechanism	[122], [123]
B10	Transparency	[94], [119], [124]
B11	Incentive Mechanism	[11], [109], [125]
B12	Traceability	[126], [127], [128], [129]
B13	Identity Management Mechanism	[109], [130], [131]
B14	Smart Contracts	[94], [117], [132]
B15	BAI/BIoT	[133], [134], [135], [136]
B16	Scalability	[108], [110], [137]
B17	System Ubiquity	[122], [128], [130]
B18	Data Intelligence	[112], [116]
B19	Data Integrity	[8], [138]

The table 4 below briefly summarises the kind of research papers studied while conducting this research.

Table 4: Summary stats of extant research analysed in this work

Research Approach	Number of Articles
Review Papers	29
Technical Papers	34
Conceptual/ Theory Based	26
Empirical	23
Case Studies	13

The table 5 below briefly summarizes the differences between healthcare system in India and western countries.

Table 5: Summary of differences between Healthcare in India and Western Countries

Parameter	India	Western Countries	References
Line of Treatments	Homeopathy, Ayurvedic & other Nature bound treatments	Allopathy	[18], [139], [140]
Insurance	Government-funded programs and out-of-pocket expenses	Insurance (Medicare, Medicaid, Commercial Health Insurance)	[141], [142]

OTC Medicines	Easy Availability without prescription	Prescription Necessary	[17], [143], [144]
Documentation	Patient Driven	System Driven	[59], [145], [146]
Insurance Coverage	Cover pre & Post hospitalization expenses, no OPD	Cover all medical expenses incurred	[140], [147]
Access & Affordability	Quality of care, Remote areas do not have access	Access to advanced healthcare facilities and infrastructure	[148], [149], [150]

- The Indian healthcare system is far more complex than other countries with many organized and unorganized players. Thus, there is an ardent need to understand the utility of blockchains in the Indian healthcare system.
- The use cases developed erstwhile cannot be replicated in the Indian context due to high variability in healthcare systems.
- India is diverse in nature with respect to its medical treatments. The country has various types of treatment available like Ayurvedic, Homeopathic, Allopathy and other nature bound treatments on the contrary to western countries where allopathy is a prevalent practice of medicine.
- The country also lacks a streamlined insurance process which leads to lot of out-of-pocket expenses by the public. Thus, it is important to assess and understand the systemic changes that need to be deployed for Blockchain Technology for its suitability to the Indian Healthcare System
- It is also essential to ensure sustainable healthcare ecosystems with a balanced premise of social, economic, and environmental factors for its holistic success.

REASEARCH METHODOLOGY

The research is primarily qualitative and exploratory, aiming to identify and evaluate stakeholders' perspectives on integrating Blockchain technology into the Indian healthcare system based on their needs. It starts by detailing healthcare challenges faced by stakeholders in Karnataka and Uttar Pradesh, then analyses these challenges for similarities related to location and demographic factors such as gender, income, and education. The study further identifies Blockchain technology attributes that could address these challenges and maps them to economic, environmental, and social sustainability dimensions. Blockchain attributes are then prioritized based on consensus from stakeholders involved in the implementation process. Later, the research identifies and categorizes implementation challenges for integrating Blockchain in Indian Healthcare Sector. Expert sentiment analysis is conducted to assess the feasibility of Blockchain adoption in Indian healthcare. Additionally, the research explores implementation challenges from the perspective of various end-users, including patients, healthcare providers, pharmaceutical companies, and insurance providers. It develops an Implementation Issue Matrix to identify and address the various challenges encountered during the implementation of Blockchain technology in Indian healthcare, providing insights into issues faced by different stakeholders in the ecosystem.

- **Identify key stakeholders of Indian Healthcare Ecosystem**

It is extremely critical and rationale to understand stakeholders' perspective to envisage a roadmap for finding assistance using Blockchain Technology that caters to their problems. The following key stakeholders of Indian Healthcare sector were identified:

- Patient or End Customer
- Medical Service Providers ((Including Physicians, Diagnostics, Support Staff etc.)
- Insurance
- Pharmaceuticals
- Government

Other two stakeholders though may not have a direct relation with the Indian Healthcare system but were important in the ecosystem are:

- Market Research Experts (gauge healthcare ecosystem on a regular basis)

- Blockchain Technologists (to gauge the adoption, applicability, customizability, and feasibility etc., of Blockchain Technology in Indian Healthcare ecosystem)

Six Different Questionnaires were used to conduct interviews with stakeholders identified.

Structured interviews were conducted with the stakeholders in online and physical mode. The Stakeholders were mainly Bangalore, Hubli, Davanagere, Bellari, and Gadag in Karnataka, as well as Lucknow, Kanpur, Prayagraj, and Banaras in Uttar Pradesh. A detail on stakeholder interaction for this research work is provided below in Table 6.

Table 6: Details on Stakeholder Interaction

Stakeholder	No of Stakeholders Interviewed (Karnataka)	No of Stakeholders Interviewed (Uttar Pradesh)
Patient or End Customer	318	342
Medical Service Providers	206	208
Insurance	72	76
Pharmaceuticals	76	81
Government Officials	58	67
Market Research Experts	64	72
Total	794	846

Phase 1

- Apply Value-Focused Thinking (VFT) to understand key challenges of Indian Healthcare System. VFT has been used as a decision aid to analyse and understand the research premise [10], [42], [109], [151], [152]. The process of VFT was conducted with the set of stakeholders to identify challenges in the Indian Healthcare ecosystem.
- Establish equivalence between requirements of Indian Healthcare with Blockchain Technology attributes that would mitigate of challenges of Indian Healthcare ecosystem and further map them to three dimensions of sustainability (Social, Economic and Environmental) which helps in sustainable transformation of Indian Healthcare System
- Based on the mapping of Blockchain Technology attributes done before, identify the crucial Blockchain attributes by frequency analysis.
- Assess these challenges for similarities related to location and demographic factors such as gender, income, and education

Phase 2

- Three stakeholders (Blockchain Technologists, Health Service Provider, Government Official) were interviewed to provide the scores to Blockchain technology Attributes identified from phase 1 to arrive at a consensus based on their individual preference. Apply MGFEM to identified Blockchain Attributes to get a rank order acc. to their importance.
- Further, the attributes identified in the phase 1 are ranked as per their priority and scores assigned by stakeholders (Blockchain Technology Expert, Health Service Provider, Government Official) using Modified Generalized Fuzzy Evaluation Method (MGFEM) & provide design recommendations for Indian Healthcare System.

Phase 3

- Structured interviews (through online mode) with Blockchain Technologists (42) are conducted to identify the issues faced for implementation of Blockchain technology in Indian Healthcare System
- Identify, analyse, and categorize the key issues using Latent Dirichlet Allocation (LDA) method when implementing Blockchain technology within the Indian healthcare system and assigning weights to each based on their significance. Further, the sentiment analysis is done for experts to gauge their views on the feasibility of implementing Blockchain technology in the Indian healthcare system.
- Identify the issues in implementation from an end user perspective (Patients, Health service providers, pharmaceutical companies, Insurance providers) using LDA method and develop an Implementation Issue matrix which helps in identifying and addressing the various issues encountered during implementation of Blockchain Technology in Indian Healthcare and understanding the challenges faced by different end-users in the ecosystem.

CONTRIBUTION

Results and Discussion- Phase 1

Based on discussions with stakeholders, fundamental objectives were identified which direct to strategic objectives identified as the three dimensions of sustainability namely social, economic, and environmental sustainability. These strategic objectives lead to strategic goal of leveraging blockchain technology for sustainable transformation of Indian healthcare. The strategic objectives are listed in the following table 7.

Table 7: Identification of fundamental objectives and aligned strategic goals

Fundamental Objectives	ID	Strategic (Sustainability) Objectives	Blockchain attributes
Execution of extensive health programs with the highest levels of trust, transparency, and traceability	F01	Socially Sustainable (SO1)	Scalability[153], [154]
Efficient crowd management, resource management, and latency, among others	F02	Environmentally Sustainable (SO2)	System Ubiquity, Distributed, Scalability[153], [154], [155], [156]
Guaranteeing transparency in the cost structure	F03	Economically Sustainable (SO3)	Scalability, Transparency[153], [154], [155], [157]
Managing elements such as remote patient monitoring and standardizing systems and procedures	F04	Socially Sustainable (SO1), Economically Sustainable (SO3)	Data Intelligence, Data Integrity, Simplified Auditing, System Ubiquity, and Scalability [153], [154], [155], [156], [158]
Navigating Governance boundaries	F05	Socially Sustainable (SO1), Environmentally Sustainable (SO2) and Economically Sustainable (SO3)	Scalability, Transparency[153], [154], [155], [157]
Consumer engagement guidelines	F06	Socially Sustainable (SO1)	System Ubiquity, Data Intelligence [155], [156], [158]
Support with regulatory or compliance requirements	F07	Socially Sustainable (SO1), Environmentally Sustainable (SO2) and Economically Sustainable (SO3)	Data Integrity, Transparency, and Non-repudiation[154], [157], [159]
Managing distribution of healthcare artifacts	F08	Environmentally Sustainable (SO2), Economically Sustainable (SO3)	Distributed. System Ubiquity and Scalability[153], [154], [155], [156]
Tracking and preventing the distribution of counterfeit drugs	F09	Socially Sustainable (SO1) and Economically Sustainable (SO3)	Transparency, Traceability, and Data Integrity[155], [157], [158], [160]
Promoting in-house manufacturing	F10	Environmentally Sustainable (SO2), Economically Sustainable (SO3)	System Ubiquity, Identity Management, Token Mechanism [155], [157], [160]
Reliable information-sharing system to prevent redundant processes	F11	Socially Sustainable (SO1), Environmentally Sustainable (SO2) and Economically Sustainable (SO3)	Trust, Scalability, and System Ubiquity[153], [154], [155], [160]
Offer reliable ratings for healthcare services	F12	Socially Sustainable (SO1), Economically Sustainable (SO3)	Trust, Scalability, and System Ubiquity [153], [154], [155], [160]
Interoperability and scalability challenges	F13	Environmentally Sustainable (SO2)	Scalability, System Ubiquity[153], [154], [158]

Ease of use and real-time solutions	F14	Socially Sustainable (SO1)	System Ubiquity, Simplified Auditing [155], [156], [158]
Costs and barriers associated with adopting technology	F15	Socially Sustainable (SO1), Economically Sustainable (SO3)	Scalability, System Ubiquity[153], [154], [158]
Transparency and accountability in R&D Investments	F16	Socially Sustainable (SO1), Environmentally Sustainable (SO2) and Economically Sustainable (SO3)	Trust, Data Intelligence, Simplified Auditing [155], [156], [160], [161]
Skill enhancement through training programs	F17	Socially Sustainable (SO1), Economically Sustainable (SO3)	Distributed, Data Intelligence Simplified Auditing, System Ubiquity, Data Integrity[154], [155], [156], [161]
Technology Innovations, development, and implementation	F18	Socially Sustainable (SO1), Economically Sustainable (SO3)	System Ubiquity, Data Integrity, Data Intelligence[154], [155], [156]
Evaluating performance of training and R&D	F19	Socially Sustainable (SO1), Economically Sustainable (SO3)	Distributed, Scalability, System Ubiquity [153], [154], [155], [160]
Data integrity, software, and technology	F20	Socially Sustainable (SO1), Environmentally Sustainable (SO2) and Economically Sustainable (SO3)	Data Integrity, Data Intelligence, Simplified Auditing[154], [155], [156], [161]
Digital Data Collection Procedure	F21	Socially Sustainable (SO1), Environmentally Sustainable (SO2) and Economically Sustainable (SO3)	Distributed, Scalability, System Ubiquity [153], [154], [158]
Automation of reliable data access	F22	Socially Sustainable (SO1)	Identity Management, System Ubiquity, Token Mechanism [155], [157], [160]
Data Utility	F23	Socially Sustainable (SO1), Environmentally Sustainable (SO2) and Economically Sustainable (SO3)	Data Intelligence, Data Integrity, System Ubiquity[155], [156], [157], [161]

Table 8 presents crucial Blockchain attributes based on the simple frequency estimation. These attributes are critical to Blockchain Technology adoption in the Indian Healthcare Ecosystem from a stakeholder perspective. List of significant attributes are Scalability, Data Integrity, Data Intelligence, System Ubiquity, Simplified Auditing, Distributed and Transparency.

Table 8: Top Blockchain Attributes based on frequency Analysis

Attribute	**Sustainability Dimension**
Scalability	Social Sustainability
Data Integrity	Economic and Environmental Sustainability
Data Intelligence	Social, Economic and Environmental Sustainability
System Ubiquity	Social, Economic and Environmental Sustainability
Simplified Auditing	Social and Economic Sustainability
Distributed	Social and Economic Sustainability
Transparency	Social and Economic Sustainability

In the next step of Phase 1, Analysis of Variance (ANOVA) is employed to assess the variation in challenges faced by stakeholders in the Indian healthcare sector across demographic parameters like state, gender, income, and education. As the data is qualitative, it was first transformed into nominal data for ANOVA analysis. The challenges in each state were categorized under the 23 fundamental objectives discussed previously. This nominal data is then utilized to identify the differences in challenges.

Python was used as a platform for ANOVA. Google Collaboratory was used as a platform for executing all the python programs. The significance level was set to 0.05. The p-Value calculated using ANOVA is compared with the significance level based on which a decision is made to either accept or reject the null hypothesis. The null hypothesis and alternate hypothesis were formulated for assessing the difference of challenges in both the states and other demographic parameters. Based on the p-Value calculated using ANOVA, the null hypothesis is rejected or it is failed to be rejected after comparing the results with significance level. The null hypothesis and alternate hypothesis formulated are as described below:

- Null Hypothesis (H_0): There is no significant difference in healthcare challenges faced by stakeholders
    - in Karnataka and Uttar Pradesh.
    - Male and female
    - In different income groups
    - with different educational backgrounds
- Alternate Hypothesis (H_1): There is a significant difference in healthcare challenges faced by stakeholders
    - in Karnataka and Uttar Pradesh.
    - Male and female
    - In different income groups
    - with different educational backgrounds

The p-Value for above parameters are States (0.3808), gender (0.6569), income (0.0378) and education (0.4260). Based on the comparison of p-Value with the significance level, it was identified that there is no significant difference in the challenges faced stakeholders from different location, based on gender or educational background. However, the analysis showed that there is significant difference in the challenges faced by stakeholders from different income groups.

The first phase of research outlines that the integration of Blockchain Technology in Indian healthcare sector can significantly enhance its efficiency and identifies the crucial attributes that address several critical challenges in the healthcare system. The analysis in phase 1 also infers that the Blockchain can act as a bridge which can reduce the gap in economic disparities and resolve the challenges faced by stakeholders of varied income groups in Indian Healthcare.

This disparity based on income underscores the importance of considering economic status when addressing healthcare challenges in India. While many issues may appear universal across different demographics, the specific needs and experiences of stakeholders vary significantly based on income. Therefore, it is essential to develop a technological solution that address the unique challenges faced by diverse income groups, ensuring equitable healthcare access for all. This can be achieved by implementing Blockchain for Indian healthcare sector which can address the economic disparities in the country with respect to healthcare and act as a ubiquitous solution for ensuring economic sustainability.

Results and Discussion- Phase 2

This study uses Modified Generalized Fuzzy Evaluation Method (MGFEM) [162], [163] to prioritize the Blockchain technology attributes identified through the process of VFT in phase 1 for sustainable healthcare transformation.

From a group decision analysis perspective, different decision makers may prioritize attributes differently, so a consensus mechanism is needed [164], [165]. MGFEM quantifies opinions expressed by decision makers using fuzzy logic. [166], [167], [168].

Now, the preference of a decision maker on multiple criteria's is very similar to that of an evaluator awarding marks to students based on quality of their answer for a question. Therefore, we modify MGFEM to evaluate preferences of multiple decision makers as shown in Table 9.

Table 9: Parameter changes in MGFEM

Old Parameter	New Parameter
Questions	Blockchain Attribute
Questions Judgement Parameters	Group of Decision makers
Marks on each question (mi)	Aggregated score of preference for each criterion

The group of Decision Makers in the research are:

- Blockchain Expert
- Healthcare Service Provider
- Government Official

They have been chosen with their apt significance in extant research and practice for Blockchain Technology implementation [169], [170]. Further, the method can also be used to enhance the number of decision makers. Figure 4 shows the standard fuzzy set which gives scores based on the level of satisfaction in MGFEM method.

	Levels of Satisfaction						
SFS	0%	20%	40%	60%	80%	100%	Scalar Product (Self)
Most Preferred	0	0	0.8	0.9	1	1	3.45
Preferred	0	0	0.8	0.9	0.9	0.8	2.9
Nuetral	0	0.1	0.8	0.9	0.4	0.2	1.66
Less Preferred	0.4	0.4	0.9	0.6	0.2	0	1.53
Least Preferred	1	1	0.4	0.2	0	0	2.2

Figure 4: Standard Fuzzy Set

For a given class(attribute), a decision maker allocates fuzzy marks between 0 to 1 to the blockchain attribute System Ubiquity based on their preference as shown in figure 5.

GFEM		Not at all Important	Least Important	Somewhat Important	Important	Very Important	Most Important	
Criteria	Decision Maker	Level of Belongingness w.r.t importance						Scalar Product(Self)
System Ubiquity	1	0	0	0.8	1	0.9	0.9	3.26
	2	0	0.4	1	0.9	0.5	0.2	2.26
	3	0	0	0.9	1	1	0.8	3.45

Figure 5: Fuzzy marks given by decision maker

Grading scale has following definitions and corresponding letter grades as shown in table 10.

The computation of final score for each blockchain attribute is a dot product of their membership values from 2 sets F and M:

$$S = \frac{F.M}{\max(F.F, M.M)}$$

Table 10: Grading scale in MGFEM

Similarity Range	Grades
90 <= MP <= 100	A
70 <= P < 90	B
50 <= N < 70	C
30 <= SP < 50	D
0 <= LP < 30	E

The similarity scores for decision makers: DM1, DM2, DM3 for the Blockchain Technology Attribute System Ubiquity are derived as 96.81%, 83.63% and 99.13% corresponding to grades A, C and A respectively as shown below in figure 6. The corresponding marks will be 95, 80 and 95 coming from the standard table of grade leading to an average score of 83.33.

System Ubiquity					
	F.M	F.F	M.M	Similarity	Grade
DM-1	3.34	3.45	3.26	96.81%	A(95)
	3.07	2.9	3.26	94.17%	
	2.08	1.66	3.26	63.80%	
	1.5	1.53	3.26	46.01%	
	0.52	2.2	3.26	15.95%	
DM-2	2.31	3.45	2.26	66.96%	
	2.22	2.9	2.26	76.55%	
	1.89	1.66	2.26	83.63%	C(80)
	1.7	1.53	2.26	75.22%	
	0.98	2.2	2.26	43.36%	
DM-3	3.42	3.45	3.45	99.13%	A(95)
	3.16	2.9	3.45	91.59%	
	2.18	1.66	3.45	63.19%	
	1.61	1.53	3.45	46.67%	
	0.56	2.2	3.45	16.23%	

Figure 6: Similarity scores for attribute system ubiquity

Similarly, the aggregate score of groups of DMs on each attribute can be used to identify order of preference for blockchain adoption in healthcare system. The complete analysis for all the Blockchain Attributes identified from VFT is shown in Figure 7.

GFEM

Criteria	Decision Maker	Gfum						Grade	Marks
System Ubiquity	1	0	0	0.8	1	0.9	0.9	A	
	2	0	0.4	1	0.9	0.5	0.2	C	
	3	0	0	0.9	1	1	0.8	A	83.33
Transparency	1	0	0.2	1	1	0.9	0	B	
	2	0	0	0.9	1	0.2	0.1	C	
	3	0	0.1	0.8	1	0.9	0.9	A	78.33
Simplified Auditing	1	0.9	0.9	0.6	0.4	0.2	0	E	
	2	1	0.8	0.6	0.3	0.2	0.1	E	
	3	1	1	0.8	0.8	0.7	0.7	A	41.67
Distributed	1	0	0	0.7	0.8	0.9	0.9	B	
	2	0	0	0.8	0.8	0.9	0.8	B	
	3	0	0	1	1	0.8	0.7	B	80.00
Data Integrity	1	0.5	0.6	0.8	0.9	0.4	0.1	D	
	2	0.4	0.4	0.9	0.8	0.3	0.1	D	
	3	0.3	0.3	0.8	0.8	0.6	0.4	C	46.67
Scalability	1	0	0	0.8	0.9	0.8	0.7	B	
	2	0	0	0.9	0.8	0.8	0.7	B	
	3	0	0	0.9	0.9	0.9	0.9	A	85.00
Data Intelligence	1	0.1	0.4	1	0.9	0.6	0.4	B	
	2	0.2	0.2	1	0.8	0.5	0.2	C	
	3	0.4	0.4	0.8	0.5	0.5	0	D	60.00

Figure 7: Complete scores for all blockchain attributes

The following priority order of Blockchain Technology attributes is developed based on decision makers' score: Scalability> System Ubiquity > Distributed > Transparency > Data Intelligence > Data Integrity > Simplified Audits

Results and Discussion- Phase 3

In Phase 3, issues in implementing Blockchain in Indian healthcare are identified and categorized. Structured interviews with Blockchain Technologists (~42) were conducted, and Natural Language Processing (NLP) was used for analysis. Topic Modelling (using Latent Dirichlet Allocation - LDA) discovers abstract topics within documents. LDA assumes that each document is a mixture of several topics, and each topic is characterized by a distribution of words. Sentiment Analysis gauges experts' views on Blockchain feasibility. The Topic Modelling method categorizes issues into 5 types, as shown in Figure 8.

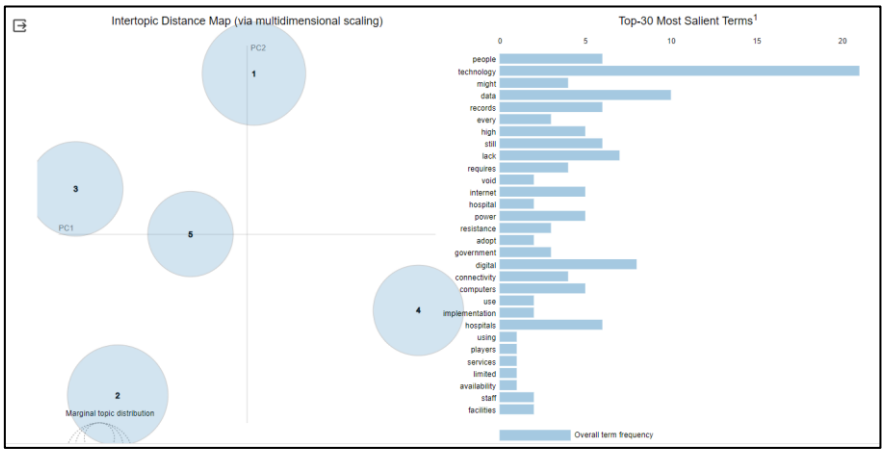


Figure 8: Five Categories of Issues using Topic Modelling

The issues were categorised to be of five types after calculating coherence and Perplexity for the model. Coherence is a measure of how well the words in a topic relate to each other. Perplexity is a measure of how well the topic model predicts new or unseen data. Figure 9 below shows the Perplexity and Coherence scores for topic 5.

Figure 9: Coherence and Perplexity scores for topic 5

Table 11 below shows the coherence and perplexity scores for different number of topics.

Table 11: Coherence and perplexity scores

Number of Topics	Coherence Score	Perplexity
4	0.421	-6.382
5	0.410	-6.525
6	0.394	-6.421
7	0.370	-6.257
8	0.318	-6.003
9	0.296	-5.986
10	0.278	-5.583

Figure 10 below shows the tokens or words identified for Infrastructure Issues with the weightage of 2.37.

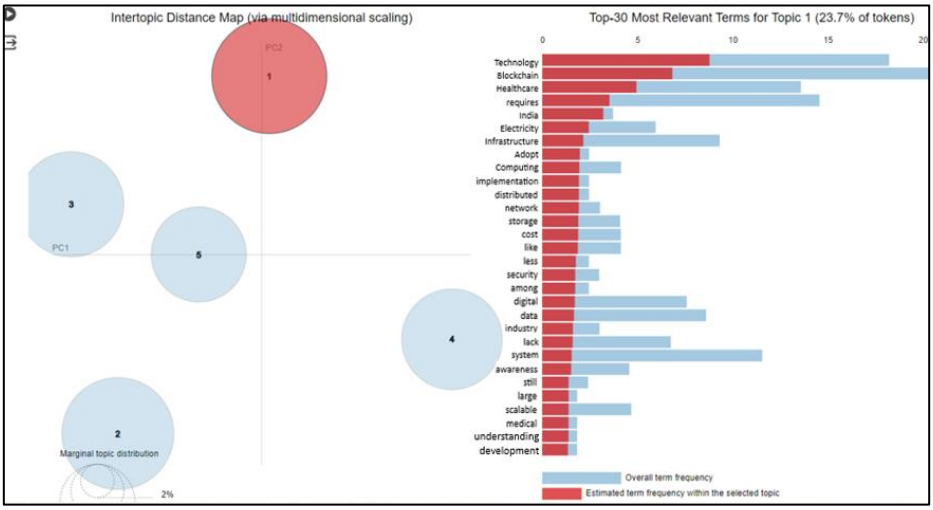


Figure 10: Infrastructure Issues

Similarly, other categories of issues were identified from topic modelling and the weightage to each of them is given based on their significance. Below are the 5 categories of Issues identified from analysis.

- Infrastructure Issues (2.37)
- Research & Training Issues (2.24)
- Governance issues (1.97)
- Social Issues (1.81)
- Change Management Issues (1.61)

A brief list of each of the issues described in figure 11 using mind mapping.

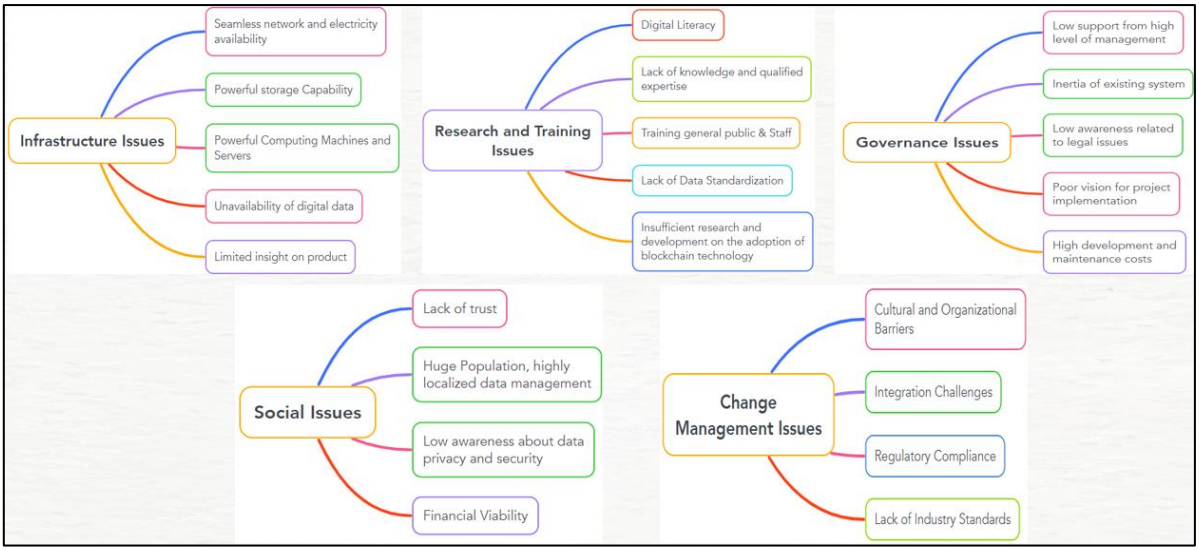

Infrastructure Issues
Seamless network and electricity availability
Powerful storage Capability
Powerful Computing Machines and Servers
Unavailability of digital data
Limited insight on product
Research and Training Issues
Digital Literacy
Lack of knowledge and qualified expertise
Training general public & Staff
Lack of Data Standardization
Insufficient research and development on the adoption of blockchain technology
Governance Issues
Low support from high level of management
Inertia of existing system
Low awareness related to legal issues
Poor vision for project implementation
High development and maintenance costs
Social Issues
Lack of trust
Huge Population, highly localized data management
Low awareness about data privacy and security
Financial Viability
Change Management Issues
Cultural and Organizational Barriers
Integration Challenges
Regulatory Compliance
Lack of Industry Standards

Figure 11: List of challenges in each category of Issues

Issues From an End User (Patient, Health Service Provider, Pharmaceutical Agencies, and Insurance Companies) Perspective

Issues from an end user (Patient) perspective post implementation of Blockchain technology are identified using Topic Modelling. The table 12 summarises the different issues faced by Patients before implementation and after implementation of Blockchain Technology

Table 12: Issues from patient before and after implementation of Blockchain Technology

Pre-Implementation	Post Implementation
Challenges faced by patients without Implementation of Blockchain Technology • Fragmented Health Records • Data Security and Privacy Concerns • Inefficient and cumbersome Insurance Claims and Reimbursements • Counterfeit Drugs and Medical Products • Limited Access to Telemedicine and Remote Care • High Medical Costs leading to Financial Burden	Post Implementation of Blockchain technology, patients are more prone to • Social Issues (6.72) • Training Issues (3.28)

Issues from an end user (Health Service Provider) perspective post implementation of Blockchain technology are identified using Topic Modelling. The table 13 summarises the different issues faced by Health Service Providers before implementation and after implementation of Blockchain Technology.

Table 13: Issues from Health Service Provider before and after implementation of Blockchain

Pre-Implementation	Post Implementation
Challenges faced by Health Service Providers without Implementation of Blockchain Technology • Limited Interoperability and Data Exchange • Fraud and Abuse • Supply Chain Inefficiencies • Loss of medical records • Inefficient Administrative Processes • Absence of trusted Review System	Post Implementation of Blockchain technology, Health Service Providers are more prone to • Infrastructure Issues (4.46) • Governance Issues (2.87) • Change Management Issues (2.67)

Issues from an end user (Pharmaceutical industry) perspective post implementation of Blockchain technology are identified using Topic Modelling. The table 14 summarises the different issues faced by pharmaceutical companies before implementation and after implementation of Blockchain Technology

Table 14: Issues from pharmaceutical companies before & after implementation of Blockchain

Pre-Implementation	Post Implementation
Challenges faced by pharmaceutical companies without Implementation of Blockchain Technology • Counterfeit Drugs • Supply Chain Inefficiencies • Lack of Clinical Trial Transparency • Absence of systematic Intellectual Property Protection	Post Implementation of Blockchain technology, pharmaceutical companies are more prone to • Governance Issues (5.28) • Change Management Issues (4.72)

Issues from an end user (Insurance industry) perspective post implementation of Blockchain technology are identified using Topic Modelling. The table 15 summarises the different issues faced by insurance industry before implementation and after implementation of Blockchain Technology.

Table 15: Issues from insurance companies before & after implementation of Blockchain

Pre-Implementation	Post Implementation
Challenges faced by insurance companies without Implementation of Blockchain Technology • Fraudulent Claims • Data Security and Privacy Risks • Inefficient Claims Processing • Limited Access to Insurance Services • Lack of Trust from policyholders/public	Post Implementation of Blockchain technology, insurance companies are more prone to • Infrastructure Issues (4.64) • Governance Issues (2.73) • Change Management Issues (2.63)

Implementation Issue Matrix was developed with the issues identified from development (Blockchain technologists) and end user (Patient, Health Service Provider, Pharmaceutical Companies, Insurance Agencies) point of view. The matrix as shown in figure 12 helps in identifying and addressing the various issues encountered during implementation of Blockchain Technology in Indian Healthcare and understanding the challenges faced by different end-users in the ecosystem.

Issue ID	Description (Implementation Issue)	Patient	Health Service Providers	Pharmaceutical Companies	Insurance Providers
I1	Infrastructure Issues		✓		✓
I2	Research & Training Issues	✓			
I3	Governance Issues		✓	✓	✓
I4	Social Issues	✓			
I5	Change Management Issues		✓	✓	✓

Figure 12: Implementation Issues Matrix

Identifying issues in the implementation of Blockchain in Indian healthcare can offer several advantages to society. Stakeholders can address barriers that hinder widespread adoption of Blockchain technology by identifying the issues. Overcoming these obstacles can lead to more accessible and efficient healthcare services for all segments of society. Recognizing issues in Blockchain implementation allows for the refinement of security measures, privacy protocols and enhance data Security and privacy. Strengthening data protection mechanisms fosters trust among stakeholders, ensuring that sensitive medical information remains secure and confidential.

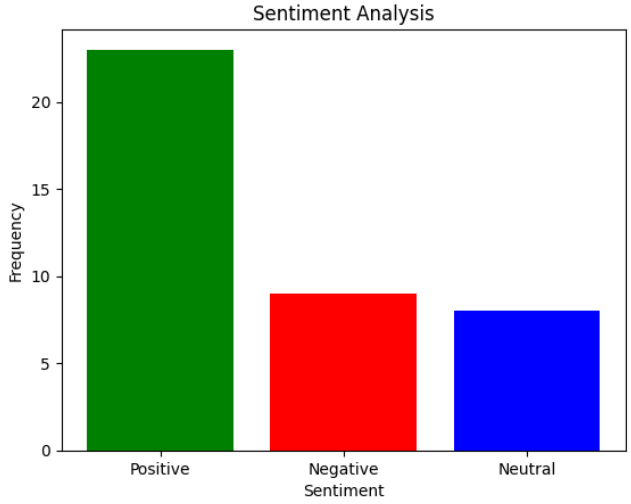
Addressing issues in Blockchain deployment can optimize supply chain management in the healthcare sector. By leveraging Blockchain's immutable ledger capabilities, stakeholders can enhance transparency, traceability, and accountability across the pharmaceutical and medical device supply chains. Recognizing barriers to Blockchain adoption allows for the elimination of inefficiencies and cost-saving opportunities. By optimizing administrative processes, reducing paperwork, minimizing fraud, and automating routine tasks, Blockchain can help healthcare organizations allocate resources more efficiently and deliver cost-effective services to patients.

Identifying issues in Blockchain implementation facilitates interoperability and collaboration among different stakeholders in the healthcare ecosystem. By addressing technical barriers and standardizing data formats, protocols, and interfaces, Blockchain solutions can facilitate

seamless data exchange and collaboration among healthcare stakeholders leading to improved care coordination and outcomes. Recognizing implementation challenges helps in mitigating fraudulent activities in healthcare transactions. By leveraging Blockchain's immutable ledger and smart contract capabilities, stakeholders can create transparent and auditable systems for tracking and verifying healthcare transactions, reducing fraud, waste, and abuse.

Identifying issues in the implementation of Blockchain in the context of Indian healthcare plays a crucial role in informing policymaking by providing insights into the challenges and opportunities associated with integrating this technology into the healthcare system. It helps policymakers design regulatory frameworks that foster innovation while ensuring patient safety, data security, and privacy protection. It allows policymakers to iterate and adapt policies in response to changing circumstances and emerging challenges. Learning from the experiences of other countries and regions in implementing Blockchain in healthcare can inform Indian policymakers about potential pitfalls to avoid and best practices to adapt.

When sentiment analysis was conducted on interviews with blockchain experts regarding the viability of blockchain implementation in Indian healthcare, the results revealed a polarity score of 0.0450 and a subjectivity score of 0.3999 as shown in Figure 13 below. The positive polarity score indicates a favourable sentiment towards the implementation of blockchain, suggesting that experts generally perceive potential benefits, albeit with some reservations. Meanwhile, the subjectivity score of 0.3999 suggests that the responses contained a moderate level of factual content rather than personal opinions, indicating a balanced perspective grounded in expertise. Together, these scores reflect cautious optimism among experts about the feasibility of blockchain in the Indian healthcare sector.




```
# Display sentiment

from textblob import TextBlob

#text = "The Blockchain demo was amazing!"
blob = TextBlob(processed_text)
sentiment = blob.sentiment

print("Sentiment Analysis:")
print("Polarity:", sentiment.polarity)
print("Subjectivity:", sentiment.subjectivity)
```

```
Sentiment Analysis:
Polarity: 0.04502717141015017
Subjectivity: 0.39917069632495145
```

Figure 13: Sentiment analysis and Polarity score for Blockchain Technologists

CONCLUSION

This paper addresses critical aspects of implementing blockchain in the Indian healthcare sector. It examines challenges faced by stakeholders, explores key attributes of blockchain, and demonstrates its potential for sustainable transformation. Additionally, it analyses integration issues and post-deployment challenges, offering weighted insights for effective problem-solving.

- The research identifies the challenges confronting stakeholders in the Indian Healthcare System, shedding light on issues inhibiting its effectiveness.
- It identifies the critical attributes of blockchain relevant for its integration into the Indian healthcare infrastructure, emphasizing its potential to streamline processes and enhance transparency.
- The findings indicated that the types of challenges faced by stakeholders differ only based on income groups but not on location, gender or educational background advocating the need for implementing Blockchain to ensure economic sustainability.
- Through analysis, the research demonstrates how adopting blockchain technology can initiate sustainable transformation within the Indian healthcare system, fostering innovation and efficiency.
- It meticulously identifies and categorizes the issues encountered during the integration of Blockchain Technology, along with post-deployment challenges faced by end-users, assigning weighted importance to each issue based on its impact.
- The Implementation Issue matrix, a product of the research, proves instrumental in policymaking by offering a structured approach to addressing challenges and facilitating the seamless adoption of technology within the Indian healthcare sector, thereby promoting sustainable transformation of Indian Healthcare.

Respondents, especially those with rural backgrounds, showed little enthusiasm for embracing technological advancements in healthcare. They were educated on the importance of safeguarding personal data, emphasizing the need to prioritize the protection of their medical information. Noticeable variations were noted in the facilities offered at different Primary Health Centres (PHCs) and District Hospitals. The developed Implementation Issue matrix serves as a valuable tool for the integration of Blockchain technology into the Indian Healthcare System, facilitating smoother implementation processes and addressing potential challenges in real-time.

FUTURE SCOPE

The research work has laid the groundwork for understanding the scope and challenges of implementing blockchain technology in the Indian healthcare sector by studying Healthcare in Karnataka and Uttar Pradesh. However, further research is necessary to expand upon these findings and address the complexities of integrating blockchain into healthcare sector in India.

India is a diverse country with many states having individual governance and policies. Future work can include studying about other states and union territories. Further research in other Indian states can help to understand regional differences in healthcare challenges and blockchain adoption. Comparative analyses can identify unique barriers and opportunities across diverse healthcare ecosystems and provide more tailored solutions.

Utilizing the theoretical framework established in this research, a real-time model for the Indian healthcare system can be developed, offering practical solutions to identified challenges. While the Value Focused Thinking (VFT) interaction with Indian stakeholders provides valuable insights, further exploration across demographic segments, such as children or individuals with cognitive disabilities, could enrich understanding.

Another potential direction involves forecasting exercises which are not within the scope of this work, future researchers could incorporate predictive analyses to address emergency scenarios like natural calamities, accidents effectively.

A detailed cost-benefit analysis can be performed to quantify the economic impact of blockchain technology in Indian healthcare. This can involve evaluating the initial costs against long-term savings and improvements in Indian healthcare delivery. The environmental implications of blockchain implementation in Indian healthcare can assessed in areas like energy consumption and medical waste recycling. Sustainable solutions like energy-efficient consensus algorithms and green blockchain technologies can be explored to ensure environmental sustainability.

Additionally, future studies might explore the integration of blockchain with emerging technologies like IoT, AI, and Big Data analytics within the Indian healthcare landscape. Such investigations would delve into potential security and privacy implications, synergies, and challenges to enhance healthcare outcomes comprehensively.

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- Shukla, R. G., Agarwal, A., Shekhar, V. & Shukla, S (2023). A fuzzy approach to assess Blockchain for sustainable transformation of healthcare. ***SN Computer Science Journal*** **(Scopus Cite Score (2021): 4.3)**
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